

Complexity and the Principles Course
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My first introduction to economics was Robert Heilbroner's wonderful little book, *The Worldly Philosophers*. In it he tells the following story about John Maynard Keynes. One evening Keynes was having dinner with Max Planck, the physicist who was responsible for the development of quantum mechanics. Planck turned to Keynes and told him that he had once considered going into economics himself. But he decided against it - it was too hard. Keynes repeated this story with relish to a friend back at Cambridge. "Why, that's odd," said the friend. "Bertrand Russell was telling me just the other day that he'd also thought about going into economics. But he decided it was too easy." That story captures two typical reactions that students often have to economics. For some it is too easy; for others it is too hard. In my view both reactions are reasonable ones—economics is simultaneously both easy and hard, and it is this dual nature of economics that makes it such a challenging course to teach.

One of the reason economics is both easy and hard is that it is a highly complex subject, which, for pedagogical reasons, we have simplified into a variety of simple models. We use these models as a foundation for various policy-relevant intertwined stories that we tell about the economy. A good principles teacher tells these intertwined stories, but at the same time reduces them into digestible, testable, bits of information, allowing his or her students to come away from the course with some knowledge that they can apply it in their later life.

In this article, I'm going to differentiate between two different story lines. One I'll call the complexity story line; the other I'll call the efficiency story line.¹ Both are important in understanding the theme of the principles course—which concerns markets and their role in society, and both come to the same bottom line—markets are pretty good institutions that do marvelous things. But both focus on different issues, and get there by entirely different routes.

The Efficiency Story

The efficiency story is a story about the *state* of competition. It is a static story, which nicely fits into a calculus (especially LaGrangian multiplier) framework. While few principles students completely understand the full efficiency story line, they do get a number of examples of it--the effect of taxes, the effect of quantity restrictions, price ceilings, and price floors on efficiency, and the way in which the economy adjusts, or

¹ There are other story lines that I will not discuss here. One that is seldom even mentioned, which would fit into a complexity story, but not in an efficiency story is the pre classical economics story of how markets divert people's attention from destructive passions to the relatively benign pursuit of material interests, and thus help hold society together. (See Albert Hirschman *The Passion and the Interests*)

does not adjust, efficiently to expansions in government spending, expansions in the money supply, or sudden changes in tastes.

It is a story taught as analytic exercises centered around graphs. One has the production possibility curve, supply and demand curves, and a variety of cost curves, all of which convey the strength of constrained maximization analytic techniques. Students learn how to maximize some function (utility, profit) subject to a constraint. Students also learn that under appropriate conditions individual maximization will lead to social maximization, although, to be honest, few principles courses students come away from the course with a deep understanding of that. They are usually struggling with the simple individual optimization story.

Many students have a hard time understanding the efficiency story because, even though it is highly simplified, it is still complicated. Since the stories are often told graphically and algebraically, languages that are difficult for many principles students to understand, the language problem makes the story difficult. In fact, many students never get around to learning the ideas of economics; they spend all the time learning math. (I believe that that is a shame, and that graphs and algebra should be as used as minimally as possible in most principles courses, but that is not the focus of this article.)

This maximization cost/benefit story line, which is a key element of the efficiency story, is a very useful one for students to learn, and, to carry through for the rest of their lives. Since principles of economics is only one of about 35 courses that make up students training in college, it seems a reasonable one to focus on. But, as with all things, it comes at a cost, and that cost is that many students never are introduced to the complexity story about how markets benefit society, and what that complexity story means for policy.

The Complexity Story

The complexity story is a story about the *process* of competition. It is based in a dynamic framework; it is an evolutionary story of an economy operating over time--drifting along on a slowly moving river with occasional rapids, none of which are directly controlled, or controllable. The complexity story is an almost magical story, one in which the invisible hand of the market takes what should be chaos, and turns it into an elegant complex structure that fits together, not perfectly, or efficiently, but sustainability. Patterns and pictures develop out of nowhere. The resulting system is not admired for its efficiency, or for any of its static properties. The system is admired for its very existence. Somehow the process of competition gets the pieces of the economy to fit together and prevents the economy from disintegrating. Observed existence, not proved efficiency, is the key to the complexity story line.

In this complexity story the market isn't desirable because of some grand sense of efficiency, and government isn't seen as something that can tweak the result in an analytic way. The market is more integrated with the entire whole, and tweaking one aspect can change another—a butterfly flapping its wings in China can change the weather pattern in the U.S.

Differences in the Two Stories

The different reactions of Plank and Russell, discussed at the beginning of this essay, can be explained by which story they were trying to understand. Judged from the perspective of a Plank, or a Russell, the efficiency story is a piece of cake; it involves elementary algebra and calculus. To Russell that story was too easy to study. The complexity story, however, is formally untellable, and is far more difficult than particle physics. It requires mathematics that was not yet developed in Keynes' time, and is only today beginning to be developed. For Plank, that story was too hard to study.

The following story told by Brian Arthur of a discussion at the first Santa Fe conference on complexity gives one a sense of why the story is so difficult. At that conference Brian Arthur was discussing the problem of including increasing returns in the economic model with one of the physicists there. The physicist said that increasing returns is like spin rotation and that therefore economics with increasing returns is very much like physics. The physicist went on to say that since there are more atoms than people, that physics must be harder than economics. But Brian Arthur changed his view by pointing out that in economics one has an additional complication. Arthur pointed out that to make the analyses comparable you would have to assume that each of your atoms had a will of their own, and what they were trying to do is to take advantage of the other atom—to do precisely what you don't want them to do. With that the physicist agreed that economics was much more difficult.

Reactions of Students to Economics

Students with mathematical backgrounds have varying reactions to this story. Many have just enough math to follow it, and find it challenging mathematically, and thus find it acceptably hard. Students with weak mathematical backgrounds find it almost impossible. But unlike Plank these same students are often attracted to the complexity story because they are not trying to deal with it mathematically. It fits their intuition, and seems wonderfully magical. So, while the mathematics associated with complexity is far too complicated for most professors teaching principles, let alone students, it is a story that intuitively fits the economy for many students, and thus they find it enjoyable. Since, at the principles level, the complexity story is told in English, not mathematics, it is much easier for the students to understand. Of course, that makes the complexity story difficult to teach.

The Evolution of the Story We Tell

Both story lines are beautifully interwoven nicely in Adam Smith's *Wealth of Nations*, which is why it was such a popular book. In many ways, it would be nice to teach principles of economics from that book, but, unfortunately, the prose is too difficult for students to follow easily. So we teach it from principles books. These principles texts have evolved from early texts, with Alfred Marshall's *Principles of Economics*, being a key text. In it Marshall developed the supply demand story, and in doing so he developed a mechanical framework that was appropriate for the efficiency story. But throughout the book he also made continual reference to the complexity story, which he stated better fit

in a biological framework. As the principles texts have evolved, the efficiency story has been given more and more space, and the complexity story less space. Paul Samuelson's principles text, which forms the template for most modern books, concentrated almost entirely on the efficiency story line. It moved from the "one thing at a time" approach of Marshall, which left the larger coordination issue up in the air, to a general equilibrium approach of Walras, which extended the efficiency story line to the explanation not only the small issues, but also to the large, general equilibrium, issues.

Important reasons why the efficiency line has been focused on are the teaching technology available and institutional structure within which economics is taught. The efficiency story fits that technology and institutional structure; in fact they have coevolved. The complexity story is much more ambiguous and much more difficult to define clear-cut questions for, and the large classes where principles of economics is generally taught requires clear cut questions and answers, to make grading easier. Thus, the complexity story did not fit the technology and institutional structure, and for the most part disappeared from the course.

A Comparison of the Elements of the Complexity Story and the Efficiency Story

In the book I edited (Colander, 2000) a number of authors considered the complexity story line in some detail, and some of the implications it would have for the teaching of economics. In that book I presented a table Brian Arthur created which distinguished the old economics (the efficiency story) from the new economics (the complexity story). Going through this table, and noting the differences, gives one a good sense of how the complexity story differs from the efficiency story.

Old Economics	New Economics
Subject seen as structurally simple	Structure seen as inherently complex
Decreasing returns	Much use of Increasing Returns
Society as a backdrop	Institutions come to the fore as a main decided of possibilities, order and structure
Discovery of immutable laws	Laws change
Language: 19 th century math, game theory and fixed point topology	Language more qualitative:
based on 19 century physics	Based on biology
Technology given	Technology fluid
Based on marginality and maximizing principles	Other principles possible
Preferences given	Formations of preferences is endogenous

Structure Seen as Inherently Complex

The efficiency story of economics is built into the standard “economics is the allocation of scarce resources among alternative means” definition that we find in most principles texts. That definition presupposes scarcity, and directs us to think about constrained maximization, given appropriate assumptions. It places broader issues outside the realm of economics, and suggests that economic problems are separable from social and political problems.

The complexity story of economics sees issues as much more interrelated. It uses a definition of economics that focuses more on coordination of individuals and continued existence of the economy as the observed phenomena needing to be explained. In the complexity approach the key question is not whether the economy operates efficiently; who knows whether it does or does not? In the complexity approach the key question is how the economy operates at all. Four billion people each doing their own thing should lead to chaos. But it does not; we somehow manage to muddle along. Looking at that question directs the analysis toward institutions which restrict individuals action, and which shape individuals to fit society’s needs for its continued existence. The efficiency story doesn’t touch such issues.

Much Use of Increasing Returns

The efficiency story is premised on nicely behaved functions and appropriate second order conditions. In presenting the models we slide in the standard assumptions: “Let’s assume that individuals have a diminishing marginal rate of substitution and that costs are increasing at an increasing rate”... The complexity story spends much more time focusing on situations with “inappropriate” second order conditions. What happens when there are increasing returns? How does competition work in those cases? What happens when there is learning by doing, and when people’s preferences are non-convex? Somehow, all these non-convexities seem to work out, and do not cause the economy to implode or explode. Competition still rules, but it is an ongoing process, not a static concept. The complexity story explores how that happens.

Once of the things I like to ask my student when introducing them to the complexity story is to intuit an average and marginal cost curve for producing a car. What they get are average and marginal cost curves that slope downward. I then ask them to contrast that with the cost curves presented in the textbooks. After doing that I have them talk about cost curves for lumpy decisions: building a new plant, or developing and marketing an idea. In all these, diminishing marginal returns shows up very little, yet in our texts we emphasize decreasing returns as central to the story of costs. The complexity story would emphasize increasing returns, learning by doing, and network externalities.

Institutions Come to the Fore

The efficiency story is essentially a mathematical story, part of whose beauty is in its generality. Constrained maximization and shadow prices are central; institutions are simply constraints that define the particular application of the general analysis.

Institutions play a much more fundamental role in the complexity story. They evolve and are a central part of the story. In the complexity story efficiency cannot be discussed separately from institutions. Institutions shape individuals; they are not only constraints; they are also the building blocks of an effectively working economy.

Laws Change

In the efficiency story there is a push to discover specific laws—the law of supply, the law of demand, the law of diminishing marginal utility, the quantity theory of money, which hold for all times. Thus, the economic system that students are presented with is one in which these universal laws are always working, and it doesn't matter whether one is in one society or another—the laws will still be the same. The complexity story is far less concerned with finding immutable laws, and more concerned with finding patterns that can be helpful in dealing with certain problems. An example is how one treats potential income in macroeconomics. In the standard approach that potential income is assumed to change only slowly due to specific microeconomic causes one can specify. In the complexity story, potential income can change suddenly as some slowly moving variable hits a critical point and changes the perceived nature of the system.

Language is More Qualitative

The language of the efficiency story focuses on calculus, game theory and in more technical stories, fixed point topology. The story is essentially deductive in nature, starting from first principles, using logic and formal language to extend those principles to broader insights. It relies on either/or's and logical deductive language, which tends to be very formal. The complexity story uses a more inductive approach. Complexity economics is based on observed reality and observed patterns. In it individuals are thought of not as logical deductive machines, but as fast pattern completers. For these fast pattern completers formal proofs are less necessary. A sense of something can be conveyed without a full formal proof of its existence, which makes the language much more qualitative.

Based on Biology

As I stated above, the efficiency story is essentially a mechanical story—telling how pieces of the economy fit together. The complexity story is more about evolution and continual change, which makes it fit better into biology than in mechanics. For example, the complexity story sees the economy in much the same way as an evolutionary biologist sees an ecosystem, as an intricate, evolving life form, which can take on a life of its own quite separate from the life of the components.

Technology fluid

Technology is appended to the efficiency story. It is hidden in the assumption of a given production function and most of the formal analysis of production takes place with a given technology. While technology can be added back as a residual, it is not the focus of the analysis. There's no consideration of how technology affects preferences, or even how technology affects the way we analyze issues. In the complexity story, technology is

center stage. Technological lock-in becomes an important issue as is the way in which technology influences choice.

Other Principles than Marginality and Maximizing Principles Possible

The workhorse in resolving the plots in the efficiency story is marginality: If the marginal benefits exceed the marginal costs you are in disequilibrium, and if they are equal you are in equilibrium. Marginality brings resolution to the efficiency stories. In the complexity story equilibrium is far less important, and will not necessarily be based on marginal conditions because of increasing returns and nonconvexities. Instead, principles such as sustainability become much more important.

Formation of Preferences in Endogenous

In the efficiency story we are born with certain tastes, which we then go out and fulfill. Given tastes are central to the conclusions of the efficiency story that markets work. In the complexity story, we are not born into this world with a complete set of tastes; many are imprinted upon us by society. In the complexity story what is inherent—i.e. deeply imprinted--and thus unchangeable, and what determined by society is an empirical question, which one would look at in the complexity approach, but which does not study in the efficiency story. This leads to two different analyses of advertising. In the efficiency story, advertising provides information or possibly disinformation. In the complexity story the purpose of advertising can be changing tastes. Thus, in the complexity story line, advertising gets more discussion than it does in the efficiency story.

Conclusion

What does all this mean for how we teach principles of economics? In the short term not a whole lot. The principles course is an institution and it cannot be changed quickly without a sudden shock from the outside or a major technological change. Some supporters of the complexity approach may see this as a problem, but I do not. In my view the efficiency story the books tell is an important one, well worth learning. The lessons learned from it, compared to the lessons learned in most other classes, makes the principles course, as it is currently taught, an essential one for students to take. It is practical, gives students new insights, and plays a central role in a solid liberal arts education. In an evolutionary sense it is stable in the short run.

In the long term however, I think the work being done on complexity means major changes for how we teach economics. There are two reasons why. The first reason is that the complexity approach is now getting much more discussion in graduate school and advanced work. In the short run the texts, and the principles course, will only add tidbits about the complexity approach as we go along, but in the long run what is taught in graduate school guides what is taught in undergraduate school. The second reason is changing technology. The complexity approach is much more conducive to computer presentation, which can deal with agent based models and simulations. As technology swings from a print medium presentation to computer medium presentation of the course,

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the complexity story will get more and more time. Eventually, it will be the central story told, and the efficiency story will be a minor sub story. At that point, if I am still around, I expect to be defending the need of the principles course to emphasize the efficiency story rather than to leave it as a sidelight.

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